User Manual

iX

Integrated X-Ray Source

For part numbers 93225, 93227

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By: Ken Wing

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Section 1

Introduction

General Product Description – 50kV, 50W, integrated HVPS, digital interface, convective cooling.

The specifications of the iX are de-rated based upon internal Oxford Instruments design guidelines. Product design, manufacturing margins, and internal testing conditions will be provided.

The Integrated X-Ray Source (iX) consists of a high voltage power supply, a digital controller and a Beryllium window X-Ray tube. iX housing consists of extruded and machined brass cylinder with removable end plates for servicing. iX is filled with silicon oil for high voltage isolation and convective cooling. Rated life of the Silicon oil is >5 years. A diaphragm is included to allow for oil volume expansion. iX is operable in any orientation. X-Ray tube is mounted to the housing with integrated flange. X-Ray tube, high voltage power supply and controller are replaceable sub-assemblies.

All electrical components are internal to the iX and are replaceable. The Cockcroft high voltage multiplier is potted. The MTBF of the multiplier is > 5 years. The MTBF of all electrical components excluding the multiplier is >10 years. No RFI or EMI is detectable from the iX external to the package. No acoustic transformer noise is detectable external to the package. The HVPS uses a resonant circuit for maximum efficiency.

iX has soft start and over current protection for the filament.

Scope

This manual describes how to operate the iX X-Ray Source and protocol demonstrated by example and explained in a process flow of Bytes.

Definitions

Throughout this manual abbreviations and words that need definition will be added here:

iX: Integrated X-Ray Tube, High Voltage Power Supply and Controller in a shielded package

Current Leakage: Detectable current on anode current monitor when kV_Prog is > 0 and uA_Prog is = 0.

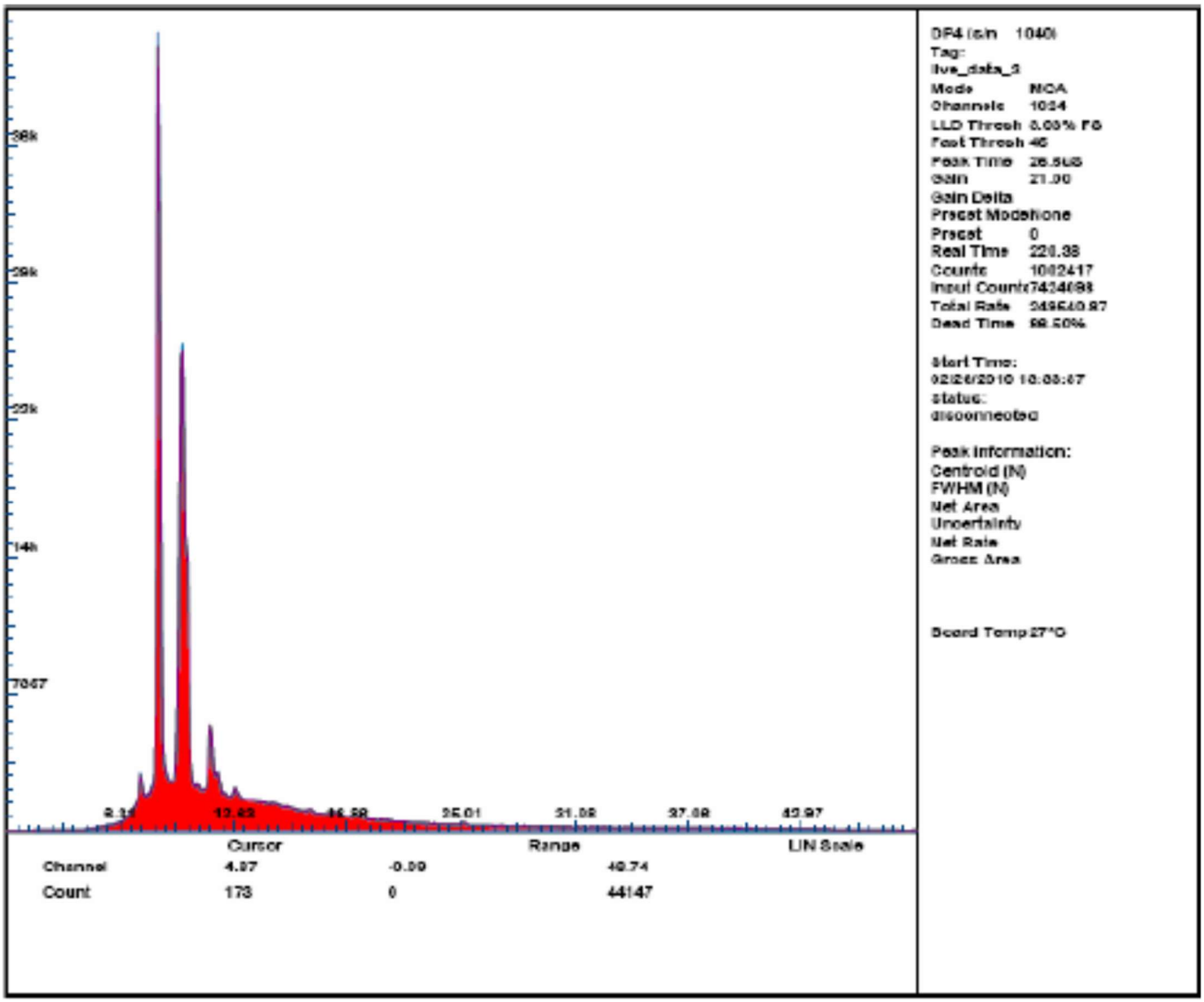
MTBF: Mean Time between Failures

CMD: Command from Host

EN: ENABLE

EOS: End Of String character 0x23

Typical Spectrum



Section 2

Mechanical Interface

Mechanical Mounting and Grounding

The iX should be securely mounted to the frame it sits in by screwing it down through the four clearance holes in the mounting feet. A chassis ground strap should be attached to the provided screw, marked “GND” on the endplate. The outline drawing provides details of mounting locations and dimensions.

Use caution around the open hole in the endplate. This hole is the vent for the oil volume expansion compensation diaphragm. Do not allow solvents or sharp objects into this hole. It is normal to observe movement of the diaphragm over changes in temperature.

Cooling your iX

The iX unit generates a significant amount of heat during operation (see specification sheet for values.) The iX must be properly cooled to ensure long operation in service. The iX is fitted with a temperature sensor that can be read out through the digital communications bus. There is a programmed temperature cut off that will disable the iX should the value of this temperature go above the specified maximum. An example of a good cooling design is a closed duct with a box fan at each end. The inlet air should be directed at the end of the iX opposite the cable connector. The cooler the iX is kept the longer it will last.

Exposure to Moisture

The iX should not be exposed to moisture, including condensing humidity. Moisture will quickly corrode the beryllium window, leading to a loss of vacuum, and destruction of the tube.

Section 3

Electrical Interface

Interface Specifications – Safety

iX has integrated a Safety Interlock Circuit which must be closed before X-Rays can be generated. During operation the interlock is closed before any kV can be generated across the X-Ray tube.

The safety conditions for closing Safety Interlock Circuit are the responsibility of the user. In general, these conditions are when it is safe to generate X-Rays. For example, the Safety Interlock Circuit should be open during all initial system power up until the time the system is ready to generate X-Rays. The Safety Interlock Circuit should be open when any cabinet doors are open or when there is human access to the iX.

Alarm Status Table

EN	***Byte 8***	***High bit***	***0 = En off***	***1 = En on***
V_FIL_FLT	***Byte 8***	***Mid High bit***	***0 = no fault***	***1 = fault***
I_FIL_FLT	***Byte 8***	***Mid Low bit***	***0 = no fault***	***1 = fault***
FIL_AGING	***Byte 8***	***Low bit***	***0 = no fault***	***1 = fault***
KV_FLT	***Byte 9***	***High bit***	***0 = no fault***	***1 = fault***
MA_FLT(ARC)-MA	***Byte 9***	***Mid High bit***	***0 = no fault***	***1 = fault***
VIN_FLT – VIN	***Byte 9***	***Mid Low bit***	***0 = no fault***	***1 = fault***
TEMP_FLT	***Byte 9***	***Low bit***	***0 = no fault***	***1 = fault***

Alarm Code Table

Status Bit	Status	Description	Effect	Resolution
Enable	0	iX can not produce X-Rays	--	Set the enable bit by sending the Enable command. See the Protocol section for information on communicating to the iX.
	1	iX can produce X-Rays	--	
Filament Open Fault	0	No fault	No effect	Unit must be re-enabled. If this error persists, it may be time to replace the tube.
	1	Filament is detected to be open	Unit is disabled	
Filament Current Fault	0	Filament is within rated current	No effect	Unit must be re-enabled. This fault may occur near the end of the tube life, or when a relatively low kV value is used with a relatively high uA value.
	1	Filament has exceeded maximum rated current	Unit is disabled	
Filament Aging	0	Filament wear is normal	No effect	Unit will operate normally, but the filament is approaching End of Life.
	1	Filament is approaching end of life	No effect	
kV Fault	0	kV output is normal	No effect	Unit must be re-enabled.
	1	kV output has exceeded 60kV	Unit is disabled	
Arc Fault	0	No fault	No effect	Unit must be re-enabled. If fault happens repeatedly, check system grounding.
	1	iX has detected an arc	Unit is disabled	
Input Voltage Fault	0	Input voltage is normal	No effect	Unit must be re-enabled once the input voltage is back to 48V. If this happens repeatedly, ensure that the 48V power supply can deliver at least 2A continuous.
	1	Input voltage is too low	Unit is disabled	
Temperature Fault	0	Internal temperature is normal	No effect	Unit must be re-enabled once the internal temperature has cooled. Ensure that the iX has adequate cooling.
	1	Internal temperature has exceeded cutoff	Unit is disabled	

Maintenance

Daily Preventative Maintenance None

Maintenance procedures will be documented and provided prior to delivery of production units.

Section 4

Interface Software Commands

4.1 Program Command from Host

Summary:

Command	PGM	KV_PROG				MA_PROG				EN	VERBOSE	
Byte #	0	1	2	3	4	5	6	7	8	9	10	11

CHECKSUM		EOS
12	13	14

Details:
See Appendix 2 for a description of each Byte #.

Program Response from iX

Summary:

Command	Pgm	EOS
Byte #	0	1

Details:
Program Response Packet

0x31, 23 = Good
0x30, 23 = Bad

4.2 Read Command from Host

Summary:

Command	Read	EOS
Bytes	0	1

Details:
Read Packet

0x3F, 23

Read Response from iX

Summary:

Read	PGM	KV_PROG				MA_PROG				STATUS	
Byte#	0	1	2	3	4	5	6	7	8	9	10

KV_MON				MA_MON				TEMP		V_IN		V_FIL	
11	12	13	14	15	16	17	18	19	20	21	22	23	24

I_FIL		HRS				TEMP		CHECKSUM			EOS
25	26	27	28	13	29	30	31	32	33	34	35

Details:
See Appendix 2 for a description of each Byte #.

Section 5

Interface Hardware Physical Layer

RS422
9600 Baud Rate
8 Bits
No Parity
No Hardware Flow Control
50 ms minimum time between commands
50 ms time out during a command

Section 6

Initial Start-up Protocol

Safe Startup Procedure
Ensure iX Interlock switch is not connected
Enable 48V to iX
Enable iX Interlock switch
Program desired kV value
Program desired uA value

Safe Shutdown Procedure
Program kV and uA values to 0
Disable Interlock switch
Remove 48V input power

Section 7

Programming

7.1 Communication Protocol Condensed

Seiko Integrated X-ray Source Transfer Protocol Rev. 3-3						7/10/09 BK	
COMMAND FROM HOST - PROGRAM							
Byte#	**PROGRAM**		**Description**	**LSB:**	**Range:**	**Example:**	
0	0X21		(ascii character)			0x21	!
1	KV_PROG	HI	16 bit KV program (hexadecimal)	1 V/b	0-50kV	50(kV) = 0xC350	C
2	"	MID_HI					3
3	"	MID_LO					5
4	"	LO					0
5	MA_PROG	HI	16 bit anode current program (hexadecimal)	20 nA/b	0-1mA	1000(µA) = 0xC350	C
6	"	MID_HI					3
7	"	MID_LO					5
8	"	LO					0
9	ENABLE		0x31 = EN, 0x30 = OFF (ascii character)			EN →'1', OFF →'0'	1
10	VERBOSE	HI	0x0 = Polling mode, 0x01-0xFF = repeat rate, 1LSB = 100ms (ascii character)			CheckSum = 0x0F	F
11		LO					F
12	CHECKSUM	HI	8 bit unsigned checksum (hexadecimal)			CheckSum = 0x0F	0
13		LO					F
14	0x23		(ascii character)			0x23	
COMMAND FROM HOST - READ							
Byte #	**READ**		**Description**	**LSB:**	**Range:**	**Example:**	
0	0x3F		(ascii character)			0x3F	
1	0x23		(ascii character)			0x23	

Seiko Integrated X-ray Source Transfer Protocol Rev. 3-3 (Continued)							7/10/09 BK
RESPONSE FROM iX - READ							
Byte #	**Read**		**Description**	**LSB:**	**Range:**	**Example:**	
0	0x3F		(ascii character)			0x3F	?
1	KV_PROG	HI	16 bit KV program (hexadecimal)	1 V/b	0-50kV	50(kV) = 0xC350	C
2	"	MID_HI					3
3	"	MID_LO					5
4	"	LO					0
5	MA_PROG	HI	16 bit anode current program (hexadecimal)	20 nA/b	0-1mA	1000(µA) = 0xC350	C
6	"	MID_HI					3
7	"	MID_LO					5
8	"	LO					0
9	STATUS	HI	BITS = {EN, V_FIL_FLT, I_FIL_FLT, FIL_AGING}			STATUS=0x80	8
10		LO	BITS = {KV_FLT, MA_FLT(ARC), VIN_FLT, TEMP_FLT}				0
11	KV_MON	HI	16 bit KV monitor (hexadecimal)	1 V/b	0-55kV	55(kV)=0xD6D8	D
12		MID_HI					6
13		MID_LO					D
14		LO					8
15	MA_MON	HI	16 bit anode current monitor (hexadecimal)	20 nA/b	0-1.2mA	1200(µA)=0xEA60	E
16		MID_HI					A
17		MID_LO					6
18		LO					0
19	TEMP	HI	8 bit temperature monitor (hexadecimal)	0.5C/b	0-127C	100(C)= 0xC8	C
20		LO					8
21	V_IN	HI	8 bit input voltage monitor (hexadecimal)	.2V/b	0-51V	51→0xFF	F
22		LO					F
23	V_FIL	HI	8 bit filament voltage monitor (hexadecimal)	.02V/b	0-5.1V	5.1→0xFF	F
24		LO					F

25	I_FIL	HI	8 bit filament current monitor (hexadecimal)	.01A/b	0-2.55A	2.55→ 0xFF	F
26		LO					F
27	HRS	HI	High byte of 16 bit hour counter (hexadecimal)	1hr/b	0-65535 hrs	65535(h)= 0xFFFF	F
28		MID_HI					F
29		MID_LO					F
30		LO					F
31	FRMWRE REV	HI	8 bit firmware revision (hexadecimal)			Ver 0=0x00	0
32	"	LO					0
33	CHECKSUM	HI	8 bit unsigned checksum (hexadecimal)			CheckSum = 0xBF	B
34	"	LO					F
35	0x23		(ASCII character)				
RESPONSE FROM iX - PROGRAM							
Byte#			**Description**	**LSB:**	**Range:**	**Example:**	
0	0x31 = Good 0x30 = Bad		(ASCII character)			0x31, 30	
1	0x27		(ASCII character)			0x27	

Program Example:
HOST: {0x21,KV_HI,KV_LO,MA_HI,MA_LO,EN, VERBOSE,CHECKSUM}
Read Example:
HOST: {0x3F}
TUBE: {0x3F,KV_PROG,MA_PROG,STATUS, KV_MON,MA_MON,TEMP,V_IN,V_FIL, I_FIL,HRS,FRMWRE_REV,CHECKSUM}
Physical Layer:
RS422
9.6 KBPS
8 Bits
No Parity
No hardware flow control
50 ms minimum between commands
50 ms timeout during a command

Checksum:
1. SUM CMD and ARG bytes into a 16 bit word (ASCII 0 should be added as 0x30, etc.)
2. SUM the high and low bytes of the 16 bit word together into an 8 bit word
3. Convert the 8 bit result to two ascii words (0x10 -> {0x31, 0x30})
4. Add the ascii words to the end of the message

7.2 Protocol Example

A. Program Command from Host (Detailed)

"Program 50KV, 1nA, EN=On, Echo back data every second, Compute Checksum, Add EOS character."

0. Program Command Byte

PROGRAM	
Byte #	0
ASCII	!
ASCII Hex	0x21

1. Calculate 50 KV:

   a. LSB (Least significant bit) → 50KV = 50,000 LSBs
   b. Convert to Hex -*(By Scientific Calculator)*→ 50,000 LSBs = 0xC350
   c. Convert to ASCII Hex *(By ASCII Table)*→ C = 0x43
      3 = 0x33
      5 = 0x35
      0 =0x30
   d. Concatenate into 16 Bit Word = { 0x43, 33, 35, 30 }

KV_PROG				
Byte #	1	2	3	4
	HI	MID HI	MID LO	LO
Decimal	50,000			
Hex	0xC350			
ASCII	C	3	5	0
ASCII HEX	0x43	0x33	0x35	0x30

2. Calculate 1mA:

   a. LSB (Least significant bit) → 20nA = 1 LSB
   b. Convert 1mA =? LSBs *(By calculation)*

$$\frac{1\text{mA}}{1} \times \frac{1 \times 10^{6}\ \text{nA}}{1\text{mA}} \times \frac{1\ \text{LSB}}{20\ \text{nA}} = 50{,}000\ \text{LSBs}$$

   c. Convert to Hex -*(By Scientific Calculator)*→ 50,000 LSBs = 0xC350

   d. Convert to ASCII Hex *(By ASCII Table)*→ C = 0x43
      3 = 0x33
      5 = 0x35
      0 = 0x30

   e. Concatenate into 16 Bit Word = { 0x43, 33, 35, 30 }

KV_MA				
Byte #	5	6	7	8
	HI	MID HI	MID LO	LO
Decimal	50,000			
Hex	0xC350			
ASCII	C	3	5	0
ASCII HEX	0x43	0x33	0x35	0x30

3. Set EN:

   a. 0x31 = On

ENABLE	
Byte #	9
ASCII	1
ASCII Hex	0x31

4. Set Verbose Mode: 1 Sec.
   0 = Polling mode, 1 -255 = repeat rate in increments of 100 ms

   a. LSB = 100 ms - → 1 sec = 10 LSBs
   b. Convert to Hex - → 10 LSBs = 0x0A
   c. Convert to ASCII Hex → 0=0x30, A = 0x41
   d. Concatenate into 16 Bit Word = { 0x30, 41}

VERBOSE		
Byte #	10	11
ASCII	0	A
ASCII Hex	0x30	0x41

5. Compute Checksum:

The checksum is computed as follows:
1. SUM CMD and ARG bytes into a 16 bit word (ASCII 0 should be added as 0x30, etc.)
2. SUM the high and low bytes of the 16 bit word together into an 8 bit word
3. Convert the 8 bit result to two ASCII words (0x10 -> {0x31, 0x30})
4. Add the ASCII words to the string

   a. Concatenate current message →
   {0x21, 43, 33, 35, 30, 43, 33, 35, 30, 31, 30, 41}

   b. Sum each byte into a 16 Bit Word →0x21
   43
   33
   35
   30
   43
   33
   35
   30
   31
   30
   41

   0x02 79
   Hi Lo

   c. Sum HI byte with LO byte: →0x02
   + 79

   0x7B

   d. Convert to ASCII 7 = 0x37, B = 0x42

6. Concatenate message + Checksum + EOS:

   {0x 21, 43, 33, 35, 30. 43, 33, 35, 30, 31 30, 41, 37, 42, 23}

7. If the message and the Checksum match, the iX will respond with 0x31, 23 and the command will be accepted.

   If the message and the Checksum do not match, the iX will respond with 0x30, 23 and the command will be ignored

B. Program Command from Host (Summary)

Summary:

Command	PGM	KV_PROG				MA_PROG				EN	VERBOSE	
Byte #	0	1	2	3	4	5	6	7	8	9	10	11

CHECKSUM		EOS
12	13	14

Details:

Byte 0: Program Packet

PGM
0x21

Bytes 1-4: Voltage Program (50 kV)

KV_PROG			
HI	MID HI	MID LO	LO
0x43	0x33	0x35	0x30

Bytes 5-8: Current Program (1 mA)

MA_PROG			
HI	MID HI	MID LO	LO
0x43	0x33	0x35	0x30

Byte 9: Enable (EN=ON)

EN
0x31

Bytes 10-11: Verbose (1 Sec)

VERBOSE	
HI	LO
0x30	0x41

Bytes 12-13: Checksum

CHECKSUM	
HI	LO
0x37	0x42

Byte 14 EOS

EOS
0x23

Read Response from iX

Summary:

Read	PGM	KV_PROG				MA_PROG				STATUS	
Byte#	0	1	2	3	4	5	6	7	8	9	10

KV_MON				MA_MON				TEMP		V_IN		V_FIL	
11	12	13	14	15	16	17	18	19	20	21	22	23	24

I_FIL		HRS				TEMP		CHECKSUM		EOS
25	26	27	28	29	30	31	32	33	34	35

Details:

Byte 0: Program Packet

0x21

Bytes 1-4: Voltage Program (50 kV)

KV_PROG				
Byte #	Byte 1	Byte 2	Byte 3	Byte 4
	HI	MID HI	MID LO	LO
ASCII Hex	0x43	0x33	0x35	0x30

Bytes 5-8: Current Program (1 mA)

MA_PROG				
Byte #	5	6	7	8
	HI	MID HI	MID LO	LO
Hex	C	3	5	0
ASCII Hex	0x43	0x33	0x35	0x30

Bytes 9-10: Status

ALARM STATUS								
Byte #	9				10			
	HI				LO			
Description	EN	V_FIL_ FLT	I_FIL_ FLT	FIL_ AGING	KV_FLT	MA_FLTL (ARC)	VIN_ FLT	TEMP_ FLT
Binary	1	0	0	0	0	0	0	0
Hex	8				0			
ASCII Hex	0x38				0x30			

Bytes 11-14: Voltage on the Instrument (50 kV)

KV_MON				
Byte #	11	12	13	14
	HI	MID HI	MID LO	LO
Hex	C	3	5	0
ASCII Hex	0x43	0x33	0x35	0x30

Bytes 15-18: Current on the Instrument (1 mA)

MA_MON				
Byte #	15	16	17	18
	HI	MID HI	MID LO	LO
Hex	C	3	5	0
ASCII Hex	0x43	0x33	0x35	0x30

Bytes 19-20: Temperature (100 C)

TEMP		
Byte #	19	20
	HI	Lo
Hex	C	8
ASCII Hex	0x43	0x38

Bytes 21-22: Voltage In

V_IN		
Byte #	19	20
	HI	Lo
Hex	8	0
ASCII Hex	0x43	0x38

Bytes 23-24: Filament Voltage

V_FIL		
Byte #	23	24
	HI	Lo
Hex	8	0
ASCII Hex	0x43	0x38

Bytes 25-26: Filament Current

I_FIL		
Byte #	25	26
	HI	Lo
Hex	8	0
ASCII Hex	0x43	0x38

Bytes 27-30: Operating Hours

HRS				
Byte #	Byte 27	Byte 28	Byte 29	Byte 30

	HI	MID HI	MID LO	LO
Hex				
ASCII Hex	0x43	0x33	0x35	0x30

Bytes 31-32: Firmware Revision

FRMWRE REV		
Byte #	31	32
	HI	Lo
Hex	8	0
ASCII Hex	0x43	0x38

Bytes 33-4: Checksum

CHECKSUM		
Byte #	33	34
	HI	Lo
Hex	8	0
ASCII Hex	0x43	0x38

Byte 35 EOS

EOS
0x23

7.3 Extract of ASCII character codes for reference

Dec	Hex	Chr
33	21	!
35	23	#
48	30	0
49	31	1
50	32	2
51	33	3
52	34	4
53	35	5
54	36	6
55	37	7
56	38	8
57	39	9
63	3F	?
65	41	A
66	42	B
67	43	C
68	44	D
69	45	E
70	46	F